

AD A 097593

AFGL-TR-80-0250

ATMOSPHERIC TRANSMITTANCE/RADIANCE
COMPUTER CODE PASCOB2

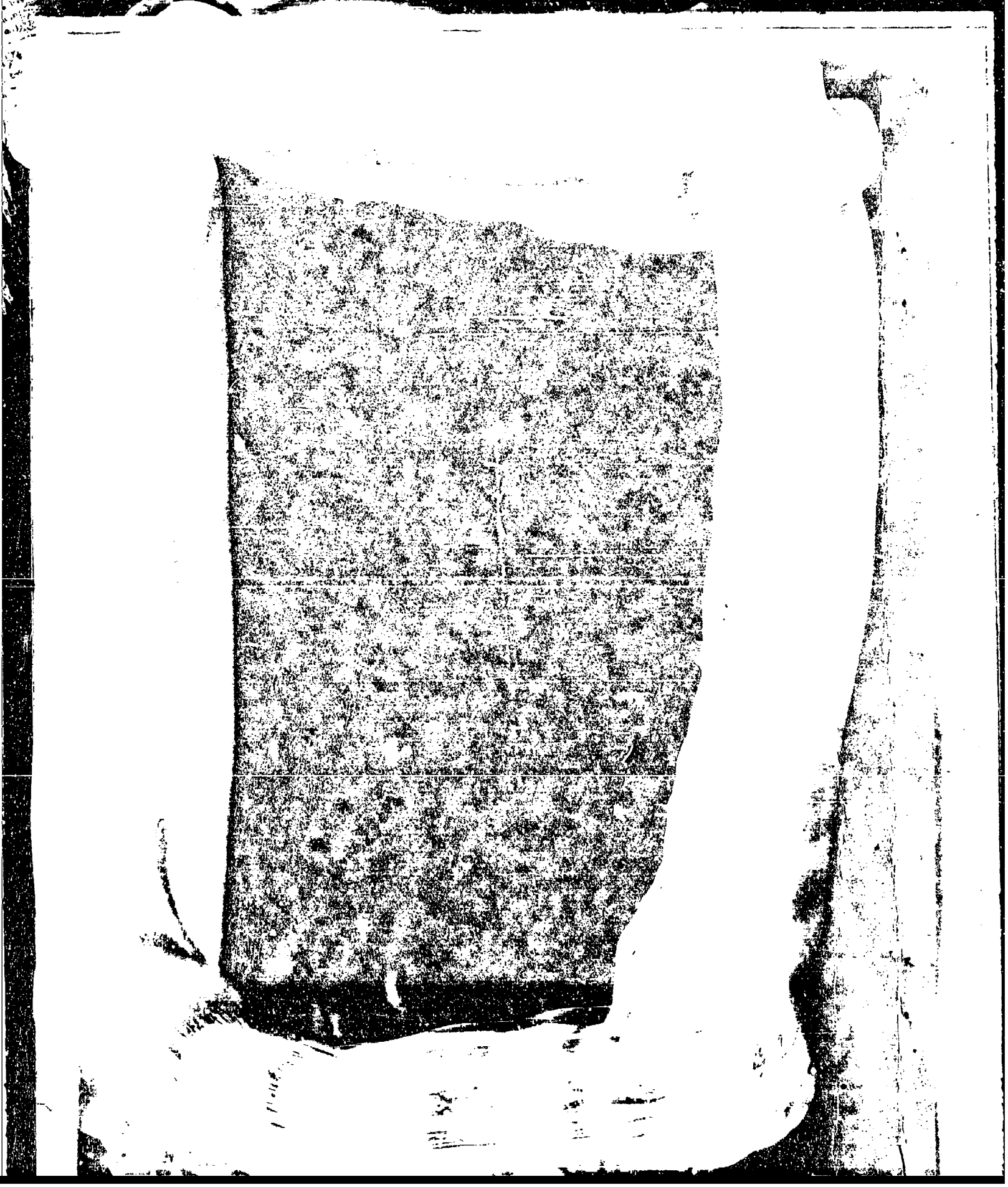
W.L. Ridgway
B.A. Boone
A.C. Ogley

Senicraft, Inc.
8839 S. Greenwood Avenue
Chicago, Illinois 60619

28 August 1980

Scientific Report No. 2

Approved for public release; distribution unlimited



Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(14) SCIENTIFIC-1

19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
(18) AFGL-TR-80-0250	ADA097593		
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED	
(6) ATMOSPHERIC TRANSMITTANCE/RADIANCE COMPUTER CODE FASCOD2		Scientific Report No. 1	
7. AUTHOR(s)		6. PERFORMING ORG. REPORT NUMBER	
(10) W.L./Ridgway R.A./Moose A.C./Cogley			
9. PERFORMING ORGANIZATION NAME AND ADDRESS		8. CONTRACT OR GRANT NUMBER(s)	
Sonicraft, Inc. 8859 S. Greenwood Avenue Chicago, Illinois 60619		(15) F19628-79-C-0120	
11. CONTROLLING OFFICE NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBER	
(11) Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Monitor/F.X.Kneizys/OPI		(16) 62101F 7670-9AM	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE	
(12) 45		8 August 1980	
		13. NUMBER OF PAGES	
		48	
		15. SECURITY CLASS. (of this report)	
		Unclassified	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report)			
Approved for public release; distribution unlimited			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)			
Radiative transfer		Non-equilibrium radiation	
Layered atmosphere		Non-LTE	
Aerosol extinction		Line shape profiles	
Atmospheric transmittance		Lorentz profile	
Atmospheric radiance		Voigt profile	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)			
<p>The fast line-by-line transmittance and radiance code FASCOD1 has been changed to include the AFGL geometry routine ATMPH and the aerosol models of the lower resolution code LOWTRAN 5. The code utilizes an optical path subject to continuous refraction and accounts for losses due to molecular and aerosol absorption and scattering. The problem of non-LTE radiance and transmission has been studied and code changes proposed. Absorption from the sub-Lorentzian CO2 far line wings is also discussed.</p>			

DD FORM 1 JAN 73 1473

Unclassified 394920

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

TABLE OF CONTENTS

SECTION		PAGE
1.	Introduction.....	5
2.	Optical Paths and Atmospheric Models.....	7
3.	Atmospheric Aerosol Models.....	15
4.	Non-LTE Transmission and Radiance.....	21
5.	A Model for the CO ₂ Continuum.....	27
6.	Atmospheric Layering.....	29
	References.....	31
	Appendix - FASCODE Users Guide.....	33

LIST OF FIGURES

FIGURE

1.	ATMPH Flow Diagram.....	10
2.	AERSOL Flow Diagram.....	18

Inspection For	
1. 3. 6. 10. 1	<input checked="" type="checkbox"/>
2. 4. 8. 12. 13	<input type="checkbox"/>
3. 5. 7. 9. 11	<input type="checkbox"/>
4. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50.	
51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100.	
101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150.	
151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200.	
201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250.	

1. INTRODUCTION

This report describes work completed and in progress on the development of a Fortran computer code FASCOD2 to calculate atmospheric transmittance and/or radiance for any given path at high spectral resolution. The present code is based on FASCODE¹ and FASCOD1² computer codes that use the AFGL line compilations³ and an approximation to the Voigt line profile based on the HIRACC⁴ algorithm. All aspects of this code that are independent of spectral resolution are to be the same as those found in the moderate spectral resolution code LOWTRAN5⁵, once it has been modified to accept the improved geometry routine discussed here. Most importantly, the two codes have a common set of model (gas and aerosol) atmospheres and are run by similar sets of control cards.

Section 2 describes how the code has been modified to calculate atmospheric paths for a spherical, refracting medium using a new AFGL geometry routine⁶ along with the six representative model atmospheres found in the LOWTRAN codes. Following this, the code has been changed to include zeroth-order scattering and absorption due to the aerosol models used in the LOWTRAN 5 code⁸. These last changes are detailed in Section 3 and the resulting interim code is documented in the Appendix.

FASCODE's radiative transfer assumes the atmospheric layers are in local thermodynamic equilibrium (LTE). For higher altitudes, the photon-driven chemistry and reduced molecular collision rate cause this assumption to be invalid. Degges⁹ has modelled the kinetics of this phenomena and produced selected single-transition population densities for given sun angles (season and time of day). Section 4 discusses how the results from Degges computations can be used to include upper atmospheric non-LTE effects in FASCODE's transmittance and radiance calculations.

The Voigt line shape model predicts a Lorentzian profile

for the line wings. It has been established that this is incorrect for CO_2 . The far wings are sub-Lorentzian. This error becomes important near band heads located next to window regions in the atmosphere where the background continuum constitutes the only absorption. The focus in the present work is the CO_2 continuum. Section 5 outlines this problem and discusses possible ways the line profiles can be modified in the far wing to account for this aspect of atmospheric radiative transfer.

The inhomogeneous model atmospheres are approximated in FASCODE by a user-specified number of homogeneous layers to simplify the radiative transfer. Consequently, line strengths and half widths are evaluated at a defined average thermodynamic state in each layer. This approach produces errors that can only be decreased by increasing the number of layers and therefore increasing the computational time. The proposed study outlined in Section 6 is to develop some knowledge concerning how layering produces errors so that they can be controlled. The goal of this work is to produce guidelines for selecting layer boundaries to minimize the error while keeping the number of layers and thus computational time acceptable.

2. OPTICAL PATHS AND ATMOSPHERIC MODELS

Program ATMPH⁶ and its subroutines, as supplied by AFGL, eliminate the need for offline programs such as LAYER⁶ and DRIVER⁶ in the preparation of the atmospheric information for FASCOD1. The program is capable of determining optical paths through the atmosphere, and includes the effects due to spherical geometry and refraction. ATMPH calculates the molecular density-weighted average temperature and pressure, along with the integrated molecular absorber amounts in each of the homogeneous layers used to approximate the atmosphere. The user can choose between six representative atmospheres, or supply his own. The number and placement of layer boundaries is also specified by the user. The goal is to incorporate ATMPH as a subroutine to FASCOD1, eliminating the need for off-line programs.

Description of the ATMPH Program: A brief description of the ATMPH program will be presented here for those users who may require a more complete understanding of the overall calculation procedure. The first control card specifies the choice of model atmosphere. There are six built-in representative atmospheres which are specified by the pressure, temperature, and molecular densities of H₂O, CO₂, O₃, N₂O, CO, CH₄, O₂, and N₂ at 34 altitudes. These model atmospheres are essentially the same as those in LOWTRAN⁵, except that the densities are in different units. One of the six model atmospheres stored in subroutine MDLATM, or a non-standard user-supplied atmosphere as read by subroutine NSMDL, is selected and stored in the common block /MDATA/.

The second control card must contain three of the following five path parameters: H1, H2, ANGLE, RANGE, and BETA. See the LOWTRAN report⁵ for allowable combinations of these parameters. Next, the desired FASCOD layer boundaries are read in. These need not correspond to the altitudes contained in the model atmospheres or include H1 or H2, the altitudes of the path end-

points. The only restriction on the choice of boundaries is that they be chosen such that the ratio of the mean half-widths in adjacent layers is not greater than 2 to 1¹. A new atmospheric profile containing both the previous altitudes and the desired FASCODÉ boundaries is formed. Pressures, temperatures, and molecular densities at the FASCODÉ boundaries are found by interpolation of the model atmosphere.

Subroutine GMTRY is called to calculate the refracted path through the atmosphere, and integrate the amounts of the absorbers along that path. Subroutine RFRPTH (which drives the integration) requires as input the set H1, ANGLE, H2 and LEN. These are determined by GMTRY using the three path parameters supplied. A final atmospheric profile, generated by RFRPTH, starts at HMIN (tangent height if any) and goes up the MAX (H1, H2) (the larger of H1 and H2). The profile is specified at H1, H2 and all of the model atmosphere altitudes and FASCODÉ layer boundaries between HMIN and MAX (H1, H2).

The determination of the refracted path, integration of the absorber amounts, and formation of the homogeneous layers is done using as layer boundaries all of the altitudes in the final profile. Once the path and integrated amounts are known, layers are merged in ATMPTH to form the desired FASCODÉ layers defined by the boundaries HMIN, H1, H2, and the FASCODÉ boundaries between HMIN and MAX (H1, H2). Finally, the layers are compared. If the ratio of the geometric thicknesses of two adjacent layers is greater than 10 or less than .1, the two layers are combined to form a single layer with a properly weighted average pressure and temperature and combined absorber amounts.

Note that the calculation of the refracted path and the absorber amounts is done using the model atmosphere altitudes as additional layer boundaries. Only after the calculation procedure is complete is the number of layers reduced. This is done so that model atmosphere data is not degraded in the process

of performing the path integrals. A general flow diagram of ATMPH is given in Figure 1.

ATMPH As A Subroutine Of FASCOD1: ATMPH and its subroutines have been added to FASCOD1 as subroutines. ATMPH is called only once to generate the layer pressures and temperatures, integrated amounts of molecules and aerosols, and the mean half-widths associated with each of the FASCODE layers. This information is stored in arrays in common block /OUTPUT/, and is passed to the FASCODE subroutine PATH. PATH is called as before in FASCODE, once for each layer, except that instead of reading the layer data from a file generated by an offline program, the data is assigned using the array values in /OUTPUT/ and /PATH/ as

PAVE = PBAR(L)

TAVE = TBAR(L)

etc.

Due to the number of times that they are referenced and central memory considerations, simple variables are preferred over subscripted variables for use in the calculation procedures.

The following gives the sequence and format of the ATMPH control cards. These now appear as a portion of the FASCOD2 control cards and will be mentioned again, but only briefly, in the FASCOD2 users guide.

Three cards control the operation of the program while other cards must be read in to define the FASCODE boundary levels, and possibly to define non-standard conditions. The formats of these cards and the meaning of the parameters are described as follows:

CARD 1: MODEL, ITYPE, IIN, IMOD, KMAX, RE
(515, 5X, F10.4)

MODEL = 0: USER SUPPLIED HORIZONTAL PATH PARAMETERS
1: TROPICAL MODEL ATMOSPHERE
2: MIDLATITUDE SUMMER

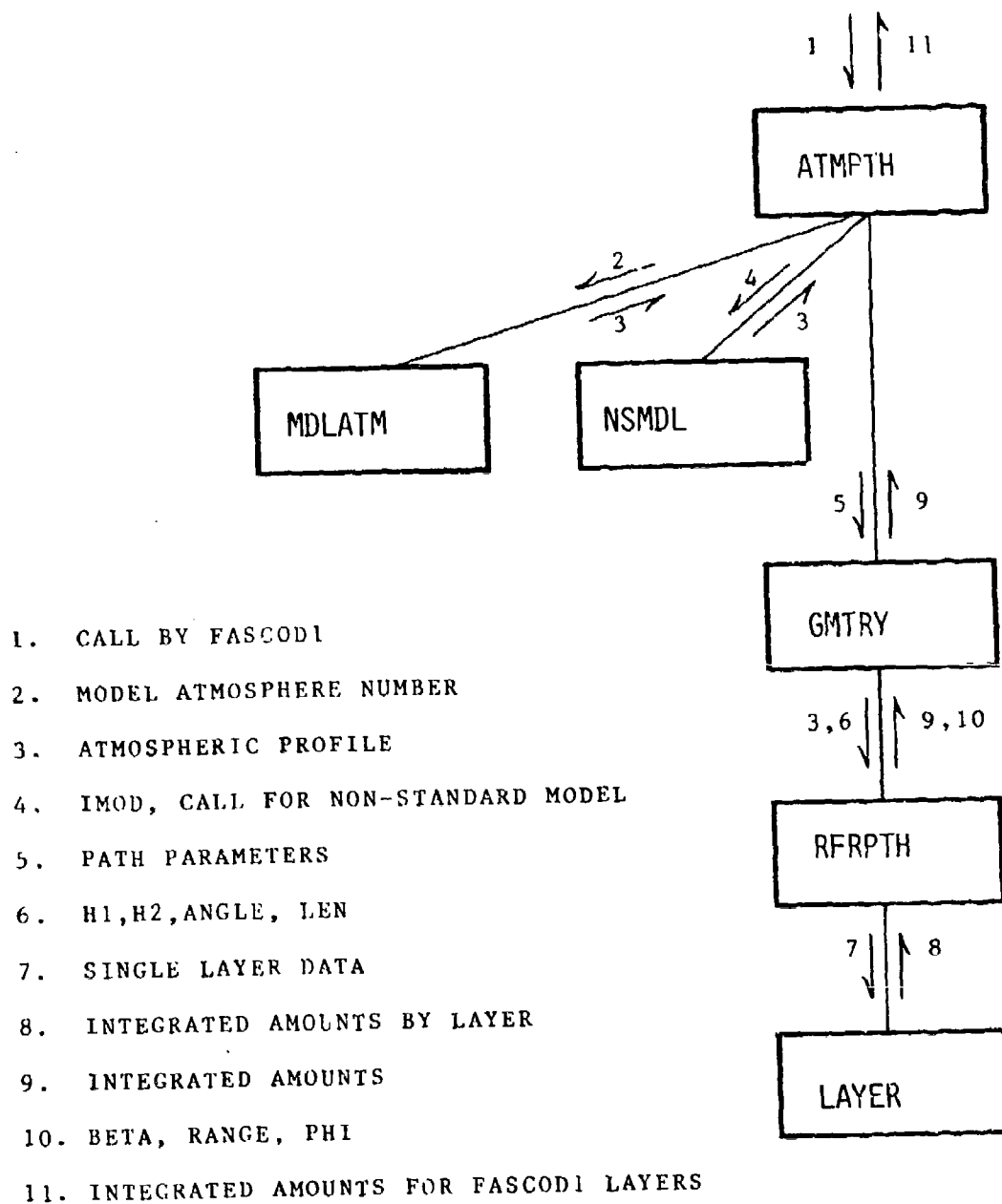


FIGURE 1 ATMPH FLOW DIAGRAM

3: MIDLATITUDE WINTER
 4: SUBARCTIC SUMMER
 5: SUBARCTIC WINTER
 6: U.S. STANDARD, 1962
 7: USER SUPPLIED ATMOSPHERIC PROFILE

ITYPE = 1: HORIZONTAL PATH (CONSTANT PRESSURE)
 2: SLANT PATH FROM H1 TO H2
 3: SLANT PATH FROM H1 TO SPACE (100 KM)

IIN NUMBER OF BOUNDARY ALTITUDES FOR THE FASCODE1
 LAYERS (REQUIRED FOR ITYPE = 2 OR 3)

IMOD NUMBER OF BOUNDARY ALTITUDES FOR USER
 SUPPLIED ATMOSPHERIC PROFILE (MODEL 7)
 DEFAULT = 34

KMAX NUMBER OF MOLECULAR SPECIES FOR WHICH
 THE AMOUNTS ARE TO BE CALCULATED. DEFAULT = 8

RE RADIUS OF THE EARTH. DEFAULTS:
 MODEL = 1, RE = 6378.39 KM
 2,3,6,7, RE = 6371.23 KM
 4,5, RE = 6356.91 KM

The formats for control cards 2 and 3 are different depending on whether the path is horizontal (ITYPE = 1) or slant (ITYPE = 2 or 3)

For a slant path:

CARD 2: H1, H2, ANGLE, RANGE, BETA, LEN
 (5F10, 4, 15)

H1 ALTITUDE OF THE OBSERVER OR RECEIVER (KM)
 H2 ALTITUDE OF THE OTHER ENDPOINT OF THE PATH (KM)
 ANGLE ZENITH ANGLE AT H1 (DEGREES)
 RANGE LENGTH OF THE PATH FROM H1 TO H2 (KM)
 BETA EARTH CENTERED ANGLE FOR THE PATH H1 TO H2 (DEG)
 LEN = 0, SHORT PATH; = 1, LONG PATH THROUGH A TANGENT
 HEIGHT. LEN IS USED ONLY WHEN ANGLE IS GT 90.0
 AND H1 IS GT H2. DEFAULT = 0.

Only three of the first five parameters need be specified; for example, H1, H2, ANGLE, or H1, H2; BETA, or H1, ANGLE, RANGE. See the comments in the subroutine GMTRY or see Reference (5) for more details on the possible combinations of these para-

meters. Next read in the boundary altitudes for the FASCODE layers (required). Format (8F10.3)

CARD 3: V1, V2
(2F10.3)

V1, V2 INITIAL AND FINAL WAVENUMBERS FOR USE IN CALCULATING THE INDEX OF REFRACTION (CM-1)

IF MODEL = 7, THE INPUT ATMOSPHERIC PROFILE IS READ IN AFTER CONTROL CARD 1 IN THE FOLLOWING FORMAT

(HEADER(1), 1 = 1, 2) (2A10)
A 20 CHARACTER HEADER DESCRIBING THE PROFILE
Z, P, T (3F10.3)
(DENSITY(K), K = 1, KMAX) (8E10.3):
TWO CARDS FOR EACH OF THE IMOD LEVELS GIVING THE ALTITUDE (KM), PRESSURE (MB), TEMPERATURE (K), AND DENSITIES OF THE MOLECULAR SPECIES (MOLECULES CM-3) AT EACH LEVEL.)

For a horizontal path:

CARD 2: Z, P, T, RANGE (DEN(K), K = 1, KMAX)
(4F10.3, /, (8E10.3))

Z ALTITUDE (KM)
P PRESSURE (MB)
T TEMPERATURE (K)
RANGE PATH LENGTH (KM)
DEN(K) DENSITY OF THE K'TH MOLECULAR SPECIES
(MOLECULES CM-3)

For MODEL = 1 to 7, only Z and RANGE are used and P, T, and DEN are interpolated.

CARD 3: NOT USED

For model 7, the input model atmosphere is read in after control card 1 as for a slant path.

Sample ATMPATH input control card sequences are given as part of the FASCODE2 users guide in the Appendix.

Verification of ATMPATH As A Subroutine Of FASCODE: ATMPATH as supplied by AFGL was capable of being run as an off-line program whose output, consisting of atmospheric information, could be read directly by FASCODE1. To verify that ATMPATH has been suc-

cessfully interfaced with FASCODE as a subroutine, comparison runs for horizontal, vertical, and slant (long and short) paths were made using the latest version of FASCOD2 with ATMPATH as a subroutine and an original version of FASCOD1 using ATMPATH as an off-line program. The codes produced identical output in all cases, indicating that the atmospheric information was being properly transferred to FASCOD2 from the newly added ATMPATH subroutine.

3. ATMOSPHERIC AEROSOL MODELS

FASCODE performs a line by line calculation of molecular transmittance and radiance through a layered atmosphere. Outside the microwave region⁷, it does not include the effects of molecular scattering or aerosol scattering and absorption. These extinction mechanisms have now been added as part of the development of FASCOD2. A new subroutine, AERSOL, gives the FASCOD2 user the option of choosing any of the aerosol models developed by AFGL for the LOWTRAN 5⁵ code. The user is referred to Reference 8 for a complete description of the available aerosol models. Molecular scattering is also accounted for in AERSOL using an expression for the attenuation coefficient taken directly from LOWTRAN.

Description of the AERSOL Subroutine: The AERSOL subroutines AERPRF, PRFDTA, EXABIN, EXTDTA, and AEREXT have been taken directly from LOWTRAN 5. The only changes that have been made to the LOWTRAN routines have been the reduction in size and number of common blocks wherever LOWTRAN variables were not used by FASCODE.

AERSOL is called initially to generate the aerosol densities at the 34 altitudes of the model atmospheres. During this first call the single aerosol control card, which contains IHAZE, ISEASN, IVULCN, and VIS, is read. Subroutine AERPRF is then called 34 times (once for each altitude) to load the desired aerosol density from the data stored in subroutine PRFDTA. These densities are unitless and used to obtain equivalent sea level absorber amounts. The chosen profile is then stored in the array EHM(34) in the common block /PROF/. At this point control returns to FASCOD2, where ATMPH is called to generate the layer data. EHM(34) is passed to ATMPH where it is handled in the same way as the molecular density profiles. The integrated aerosol amounts are stored in the array AWKAER(L) and are assigned to the simple variable name WKAER in subroutine PATH.

AERSOL is subsequently called once for each layer. Its function then is to load molecular scattering and aerosol scattering and absorption "effective optical depths" into the FASCOD2 array ABSRB(J), over the frequency range of V1ABS to V2ABS in increments of DVABS, as specified by FASCOD2. Note that this array was previously used by FASCODE for molecular continuum data such as H₂O and N₂. It now contains in addition to the continuum data, molecular scattering and aerosol extinction which are also relatively slow functions of frequency.

The effective optical depths are given by the product of the integrated amount and the appropriate attenuation coefficient. For aerosol scattering or absorption, the amount WKAER is known from ATMPFH. The coefficients are a function of the aerosol model chosen, the relative humidity (for altitudes between 0 and 2 km), the altitude region, and the frequency. During AERSOL's first call within the layer loop EXABIN is called to obtain a set of altitude and frequency dependent attenuation coefficients using the data stored in subroutine EXTDTA. These are stored in the arrays ABSC(4,40) and EXTC(4,40), corresponding to the 4 altitude regions and 40 wavelengths contained in VX2(40).

The frequency loop in aerosol calls AEREXT to obtain the coefficients at each frequency by interpolation of the ABSC and EXTC arrays. The aerosol optical depths are then simply:

$$\tau_{A,S} = (EXT-ABS) * WKAER$$

$$\tau_{A,A} = ABS * WKAER$$

The expression for the molecular scattering optical depth was taken directly from LOWTRAN as:

$$\tau_{m,s} = \nu^4 / (9.26799 \cdot 10^{18} - 1.07123 \cdot 10^9 \cdot \nu^2) \left(\frac{P}{P_0} \right) \left(\frac{T_0}{T} \right) S. \quad (3.1)$$

For the case where the current FASCOD2 layer is not totally contained within one of the aerosol regions, 0-2 km, 2-10 km, 10-30 km, or 30-100 km, a linear combination of the altitude dependent aerosol attenuation coefficients is used.

The overall flow of the aerosol routine is shown in Figure 2. AERSOL As A Subroutine Of FASCODE: As mentioned earlier, AERSOL is called once to initialize the aerosol density profile and then once for each layer to calculate the effective optical depths and load them into the ABSORB array. The R1 array, which eventually has ABSORB merged into it, now contains total extinction data rather than just molecular absorption data. The calculation procedure in FASCOD2 is correct for transmittance but must be modified for emission calculations. Emission is proportional to absorption, not extinction, therefore the statement in subroutine EMIN which calculates blackbody radiation must be modified by the scattering albedo. The original equation,

$$\text{BBRAD}(I) = (1 - \text{TR}(I)) * \text{BB} \quad (3.2)$$

has been changed to

$$\text{BBRAD}(I) = (1 - \text{TR}(I)) * (1 - \text{ALB}) * \text{BB}. \quad (3.3)$$

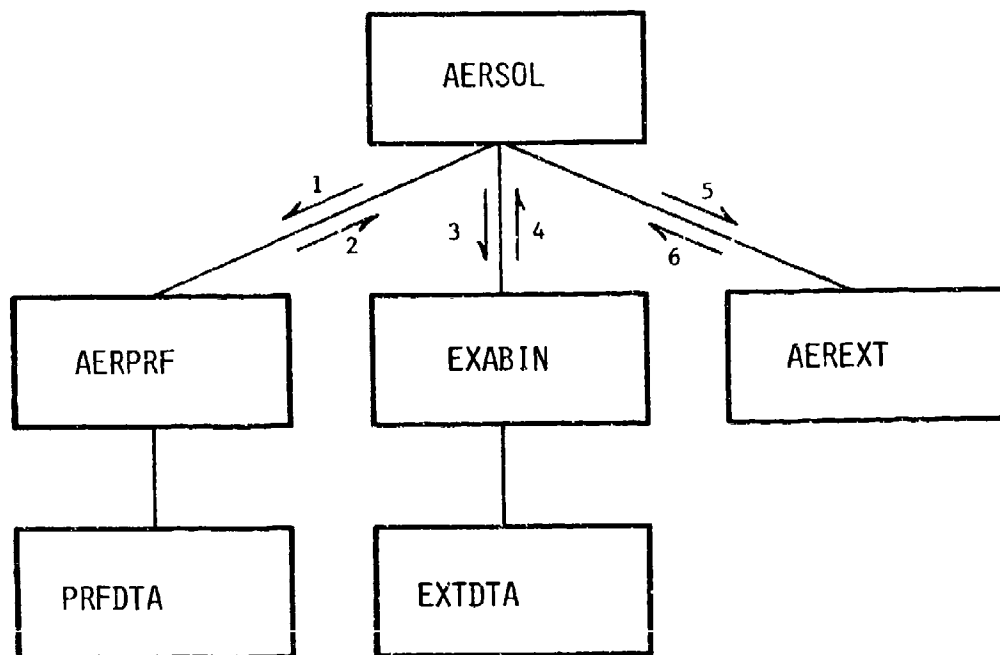
where

$$\text{ALB} = \frac{k_s}{k_E}.$$

The user is referred to References 5 and 8 for guidance in choosing the proper aerosol model for his particular problem. Once the choice is made, a single aerosol control card, having the following format, controls the aerosol routine:

```
IHAZE, ISEASN, IVULCN, JP, VIS
FORMAT (4(4x,I1), 5x, E10.3)
```

where,



1. CONTROL PARAMETERS
2. PROFILE EHM(34)
3. CONTROL PARAMETERS
4. ABSC(4,40),EXTC(4,40)
5. ABSC(4,40),EXTC(4,40)
6. ABSV(4),EXTV(4)

FIGURE 2 AERSOL FLOW DIAGRAM

IHAZE = 0 no aerosol attenuation included in the calculation.
 = 1 RURAL extinction, 23 km VIS.
 = 2 RURAL extinction, 5 km VIS.
 = 3 MARITIME extinction, 23 km VIS.
 = 4 MARITIME extinction, 5 km VIS.
 = 5 URBAN extinction, 5 km VIS.
 = 6 TROPOSPHERIC extinction, 50 km VIS.
 = 7 USER DEFINED extinction, 23 km VIS. (Read into
 the program immediately after CARD1. Refer to the
 main program LOWEM in Appendix A⁵ for the input
 format of the coefficients).
 = 8 FOG1 (Advection Fog) extinction, 0.2 km VIS.
 = 9 FOG2 (Radiation Fog) extinction, 0.5 km VIS.

ISEASN = 0 season determined by the value of MODEL;
 SPRING-SUMMER for MODEL = 0,1,2,4,6,7
 FALL-WINTER for MODEL = 3,5
 = 1 SPRING-SUMMER
 = 2 FALL-WINTER

IVULCN = 0,1 BACKGROUND STRATOSPHERIC profile and extinction
 = 2 MODERATE VOLCANIC profile and
 AGED VOLCANIC extinction
 = 3 HIGH VOLCANIC profile and
 FRESH VOLCANIC extinction
 = 4 HIGH VOLCANIC profile and
 AGED VOLCANIC extinction
 = 5 MODERATE VOLCANIC profile and
 FRESH VOLCANIC extinction

JP = print option parameter to be used in the final version
 of the code; JP may be ignored at this time.

VIS = meteorological range (km)
 (when specified, supercedes default value set by
 IHAZE).

Verification Of The AERSOL Routine: To verify that the aerosol routines function properly as subroutines of FASCOD2, comparisons were made with LOWTRAN results. LOWTRAN 5 gives separate aerosol contributions to transmittance. FASCOD2 does not do this, so statements were added to artificially suppress molecular absorption by dividing molecular absorber amounts by 10^{20} . FASCOD2 was then run for transmittance, and the results checked with LOWTRAN 5 results for aerosol absorber amounts, attenuation coefficients, and transmittance. Vertical paths were used to eliminate any differences caused by the different geometry routines now used in these two codes.

The comparisons made are convincing evidence that FASCOD2 handles the aerosol models and calculations correctly. The improved geometry routine now used in FASCOD2 uses a slightly different humidity calculation for the 0-2 km region than used in LOWTRAN 5. This causes some very small differences in the numbers returned by the two codes for aerosols only. Since the improved geometry routine is being added to LOWTRAN by AFGL, a common humidity calculation will be agreed upon and put into both codes.

4. NON-LTE TRANSMISSION AND RADIANCE

Introduction And Formalism: The FASCODE algorithm constructs molecular spectral absorption functions using an approximate Voigt line-shape profile for each active transition between molecular vibrational-rotational (VR) states. The line-strength and half-width associated with each transition are evaluated at the density-weighted average temperature and pressure of each of the homogeneous layers that together approximate the inhomogeneous atmosphere. The line broadening is principally determined by collisions in the higher-pressure lower atmosphere (Lorentz region) and by the thermal equilibrium velocity distribution in the upper atmosphere (Doppler region). Line-strengths, on the other hand, are mainly determined by the populations of the two VR states which each transition connects.

Under conditions of local thermodynamic equilibrium (LTE), collisions cause the molecular VR states to have a Boltzman population distribution. In this case, line-strengths can be calculated in terms of the strengths at a reference temperature T_0 , since one knows how the upper and lower state populations vary with temperature. FASCODE performs this calculation together with the half-width calculation as explained in Ref. 1. Reference line-strengths and half-widths, as given by the line parameters compilation³ at a reference temperature (296°K) and pressure (1013mb), are modified to give the actual strength and both Doppler and Lorentz widths according to the average layer temperature and pressure. Under LTE conditions, the layer transmission spectral function is calculated line-by-line by HIRAC and LBLF4. The layer radiance is then directly calculated from the optical depth for molecular absorption using the Planck function, which represents thermal equilibrium population ratios, evaluated at the average temperature of the layer T.

The transmittance and radiance in the lower atmosphere can be represented quite adequately in terms of the LTE model out-

lined above. However, at altitudes above 30-50 km, the lower gas density enhances the characteristic time between collisions and slows the rate of VR state 'mixing'. The molecular VR state populations tend to be driven from equilibrium by the local radiation field. Although collisions are not sufficient to bring about a thermal population distribution among the vibrational states, both translational and rotational degrees of freedom largely remain in thermal equilibrium at the kinetic temperature T . Thus, the line half-widths and line-shapes are not significantly altered in the higher altitude non-LTE case.

A computer code capable of modeling the principal non-equilibrium vibrational populations of H_2O , CO_2 , O_3 and NO has been previously developed⁹. We are adding to FASCODE the capability to use this high-altitude vibrational state population data in order to allow for a more realistic calculation of both transmission and radiance in this region. Minor modifications can be made to the basic FASCODE algorithm to allow for the line-by-line construction of the spectral absorptance function for non-equilibrium vibrational populations. Several more extensive changes will allow the code to handle non-LTE radiance.

In the non-LTE case, the general expression for the strength of a single line in terms of the line-strength at the reference temperature is

$$S = S(T_o) \left[\frac{\rho_l - \rho_u}{\rho_l^o - \rho_u^o} \right] \quad (4.1)$$

where the ρ 's are upper and lower single VR state populations for the homogeneous layer and the superscript 'o' refers to equilibrium conditions at the reference temperature T_o . The total optical depth τ_v is obtained by summing the single line absorption coefficients K_v^1 , weighted by the absorber amounts W_1 , over all of the active lines for all molecules:

$$\tau_v = \sum_1 W_1 K_v^1 \quad (4.2)$$

The spectral radiance per line R_v^i for a thin layer of gas (no self-absorption) is related to the absorption coefficient for that line by

$$R_v^i = \frac{2hv^3}{c^2} \left[\frac{\rho_u^i}{\rho_l^i - \rho_u^i} \right] K_v^i, \quad (4.3)$$

giving a total emission $R_v = \sum R_v^i w_i$ for all lines in a thin layer. Note that at equilibrium, the ratio of emission to absorption R_v^i/K_v^i reduces to the Planck function

$$B_v(T) = \frac{2hv^3}{c^2} \left[\frac{1}{\frac{hv}{kT} - 1} \right] \quad (4.4)$$

for each line. The Planck function then also similarly relates total LTE emission and absorption. This general relationship does not apply in the non-LTE case.

It will be assumed that the line-shapes for absorption and radiance in the non-LTE problem are the same as they would be at equilibrium, so the K_v^i and R_v^i differ from their equilibrium counterparts only by factors which depend on VR single state populations. The actual populations ρ_l and ρ_u for a particular layer can be calculated from the vibrational state population data of the Degges model, assuming the rotational sub-states follow the Boltzman distribution. Reference single state populations ρ_l^0 and ρ_u^0 can also be calculated for the thermal equilibrium distribution at T_0 . Therefore, both K_v^i and R_v^i can be calculated line-by-line and properly summed to give the total optical depth and radiance.

The model we then have is one containing an equilibrium gas A and a non-equilibrium gas B. At lower altitudes, only gas A is active. Above 30-50 km., the majority of lines are still in equilibrium, but some lines must be included in gas B rather than A. The total optical depth is

$$\tau_v = \tau_v^A + \tau_v^B, \quad (4.5)$$

where both τ_v^A and τ_v^B must be calculated line-by-line. The total radiance for a thin layer is

$$R_v = R_v^A + R_v^B, \quad (4.6)$$

where $R_v^A = \tau_v^A B_v(T)$, and R_v^B is calculated line-by-line. The total radiant intensity including self-absorption for a finite homogeneous layer is

$$I_v^{\text{RAD}} = \frac{R_v}{\tau_v} [1 - e^{-\tau_v}]. \quad (4.7)$$

A Preliminary Outline Of Planned Code Modifications For Non-LTE Transmission and Radiance: We describe somewhat schematically in this section a series of code changes which will serve to provide FASCODE with the capability to use non-equilibrium vibrational level populations for improved radiance and transmission calculations. Every effort will be made to have the code function as it does presently for calculations under LTE conditions. This will be accomplished by constructing new routines when necessary rather than modifying existing ones.

The non-LTE calculation will require two new data bases. Vibrational level population data of Degges and Smith⁹ will be read and stored for those levels which are not at thermal equilibrium. The data should cover an altitude range appropriate to FASCODE and it can be expected to vary with the solar angle under daylight conditions and with the change to night conditions. The second data base will consist of a line parameters file which will have an expanded format to include a vibrational transition ID or some additional labels to facilitate matching lines with corresponding non-LTE levels.

Along with the new data bases, several new routines are being created. A new routine will read the non-LTE line data

and vibrational level populations. It will prepare two new sets of line-strengths for use in the non-LTE absorptance and radiance calculations. Another routine will later calculate the total radiance for each completed layer.

The complete program will function as follows. At lower altitudes, HIRAC1 will ignore the non-LTE data in the revised line file and proceed without modification. The non-LTE routines will be triggered above a certain altitude. At this altitude and above, HIRAC1 will calculate absorptance line-by-line using the appropriate non-LTE line-strengths where necessary. A second line-by-line calculation will be performed and the results stored on a second file for later use in the radiance calculation. This second calculation can be done by HIRAC1, using specially modified line-strengths. The radiance routines will be modified to give the proper total layer transmittance and radiance using the two stored spectral functions. The single layer results will then be merged with those of previous layers using the current algorithm.

5. A MODEL FOR THE CO₂ CONTINUUM

The line-shapes of CO₂ and most other molecules are usually taken to be Lorentzian in the high pressure, collision-broadened limit. The two-parameter Lorentzian shape function is completely specified by a strength S , which is the integral of the shape function, and the line width at half maximum α . The experimental evidence suggests that the actual shape function for CO₂ is approximately Lorentzian within about 15 half-widths of the line center¹⁰, but becomes sharply sub-Lorentzian at greater distances from the central peak^{11,12}. This effect can be understood in light of the limitations of collisional models that give the Lorentzian line-shape. A simple impact approximation which assumes that collisions occur instantaneously gives the Lorentzian shape with a half-width $\alpha \sim \tau^{-1}$, where τ is the average time between collisions^{13,14}. The large frequency separations $(\nu - \nu_0)$ typical of the far wings correspond to very short time scales which may be shorter than the actual average collision duration. Therefore, it is not surprising that the impact approximation and the Lorentzian shape associated with it should not properly describe behavior in the far wings.

The initial approach that we will use to better model the real line-shape in the far wings is to replace the Lorentzian shape function f_L by the more general multiparameter shape function f in the far wings:

$$f = f_L e^{-a[|\nu - \nu_0| - \nu_{\min}]^b}; \text{ if } |\nu - \nu_0| > \nu_{\min}. \quad (5.1)$$

The parameters a , b , and ν_{\min} can be determined from the experimental data of Winters¹¹ and Burch¹². Winters has used this shape function to fit measurements of the far wings above the 2400 cm⁻¹ band head. The data of Burch suggests that the same form may also be used for the 3800 cm⁻¹ and 7000 cm⁻¹ bands. We will make the further assumption (consistent with the limited data which is available) that all of the atmospheric CO₂ lines

can be modelled with the same shape function f , with only S , and α to be specified for each line.

The modification of the far wing CO_2 line-shape in FASCODE is presently in its preliminary stages. (Since the FASCODE report of January '78, the problem of water vapor continuum absorption is being addressed through work at AFGL²). The sub-Lorentzian shape function will be used to construct a function representing the CO_2 continuum, in a fashion similar to the way the water vapor continuum has been modelled. An AFGL routine is available which combines lines to considerably reduce the computational time required to construct a continuum function line-by-line¹⁵. The problem of how one can properly 'match' the pressure-dependent continuum functions to an efficient line-by-line calculation of the other four functions which represent the line center remains to be more adequately addressed.

6. ATMOSPHERIC LAYERING

The interim code, FASCOD2, models the inhomogeneous atmosphere with a series of homogeneous layers. The user is required to specify, in addition to the path and model atmosphere parameters, the altitudes where the layer boundaries are to be placed. The geometry package ATMPTH then 'traces' the (generally) curved path through each layer and computes an average pressure \bar{P} and temperature \bar{T} plus molecular and aerosol amounts for each layer. Presently, the user has no guidelines to aid in choosing layer boundaries. To ensure that the result is sufficiently accurate, a large number of layers can be used, but only at the expense of computational time, which is particularly disadvantageous if a large range of wave numbers is to be studied. Another problem can arise if too few layers are used. Aside from having to deal with a somewhat uncontrollable error, it is possible to violate the requirement that the ratio of average pressures in consecutive layers be less than two (2). If this happens, execution will stop in mid-program.

We have planned several kinds of changes to overcome these problems. This work has not been completed, but we will outline the planning that has taken place in the last year. We plan to make code modifications in several stages. The first and most obvious change will be to construct a routine that prepares the set of layer boundaries based on one or two conditions which the user can specify. A condition suggested by AFGL is that the maximum pressure and temperature variations within each layer be fixed by the user. This kind of condition can guarantee that the approximation of homogeneity within each layer is a good one.

If it proves feasible, the layering routine may be expanded to base the choice of layer boundaries on a wider set of criteria. For instance, the allowable error in any single layer should depend on what part of the total absorption or radiance is due to that layer. Because this error can vary with the kind of path

involved and with the wavenumber region of interest, it is very difficult to decide how the layer boundaries should be chosen in order to minimize the total error. Based on these kind of considerations, we will undertake a study of the error which results when running the code, by using the same path and varying the layering scheme. The 'error' can be calculated by comparison with a reference run which has a sufficiently large number of layers. A measure of the error in the transmission for the frequency interval from ν_1 to ν_2 is, for example,

$$\frac{1}{|\nu_1 - \nu_2|} \int_{\nu_1}^{\nu_2} \left| \frac{T_\nu - T_\nu^{\text{ref}}}{T_\nu^{\text{ref}}} \right| d\nu . \quad (6.1)$$

We have written a short routine to evaluate this error by comparing a statistical sample of the output of the two runs. The error can be studied as a function of the number and position of layer boundaries, the type of path specified, and the wavenumber region. The goal of this parametric study will be to develop a more adequate set of criteria for the specification of layer boundaries. The end product may be either a set of guidelines for the user, or a more sophisticated layering algorithm which will function side-by-side with the geometry package.

REFERENCES

1. Smith, H.J.P., Dube, D.J., Gardner, M.E., Clough, S.A., Kneizys, F.X., and Rothman, L.S., "FASCODE - Fast Atmospheric Signature Code (Spectral Transmittance and Radiance)," AFGL-TR-78-0081 (1978).
2. Clough, S.A. and Kneizys, F.X., "FASCOD1," private communication (1979).
3. McClatchey, R.A., Benedict, W.S., Clough, S.A., Burch, D.E., Calfee, R.F., Fox, K., Rothman, L.S., and Garing, J.S., "AFCLRL Atmospheric Absorption Line Parameters Compilation," AFCLRL-TR-73-0096 (1977).
4. Clough, S.A., Kneizys, F.X. and Chetwynd, J.H., "Algorithm for the Calculation of Absorption Coefficient-Pressure Broadened Molecular Transitions," AFCLRL-TR-77-0164 (1977).
5. Kneizys, F.X., Shettle, E.P., Gallery, W.O., Chetwynd, J.H., Abreu, L.W., Selby, J.E.A., Fenn, R.W., and McClatchey, R.A., "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 5," AFGL-TR-80-0067 (1980).
6. Gallery, W.O., Kneizys, F.X., and Clough, S.A., "ATMPH-Computer Code Atmospheric Path," private communication (1979).
7. Falcone, V.J., Abreu, L.W., and Shettle, E.P., "Atmospheric Attenuation of Millimeter and Submillimeter Waves: Models and Computer Code," AFGL-TR-79-0253 (1979).
8. Shettle, E.P. and Fenn, R.W., "Models for the Aerosols of the Lower Atmosphere and the Effects of Humidity Variations on Their Optical Properties," AFGL-TR-79-0214 (1979).
9. Degges, T.C. and Smith, H.J.P., "A High Altitude Infrared Radiance Model," AFGL-TR-77-0271 (1977).
10. Eng, R.S. and Mantz, A.W., "Tunable Diode Laser Measurements of H₂O and CO₂ Line Parameters in the 10-15um Spectral Region," AFGL-TR-78-0178 (1978).
11. Winters, B.H., Silverman, S., and Benedict, W.S., J. Quant. Spectry. Radiative Transfer 4, 527 (1964).
12. Burch, D.E., Gryvnak, D.A., Patty, R.R., and Bartky, C.E., J. Opt. Soc. Am. 59, 267 (1969).

13. Huber, D.L. and VanVleck, J.H., Rev. Mod. Phys. 38, 187 (1966); VanVleck, J.H. and Huber, D.L., Rev. Mod. Phys. 49, 939 (1977).
14. Clough, S.A., Kneizys, F.X., Davies, R., Gamache, R., and Tipping, R., "Theoretical Line Shape for H₂O Vapor; Application to the Continuum," AFGL preprint (1980).
15. Clough, S.A. and Kneizys, F.X., private communication (1980).

APPENDIX - FASCODE USERS GUIDE

Introduction: In the course of adding the ATMPTH and AERSOL routines to FASCOD1 several new control cards were introduced. In addition, some of the original FASCOD1 control cards have been consolidated to simplify the entire control deck structure.

The complete input card sequence is listed below. The routine with which the card is associated is also given.

Card 1 from FASCOD1 main

XID(1), I = 1,7
(10A10)

Card 2 from FASCOD 1 main

IHIRAC, ILBLF4, ICNTHM, IAERSL, IEMIT,
ISCAN, IFILTR, IPLOT, IATM, MPTS, NPTS
(9(4X,11), 25X, 215)

Card 3 from FASCOD1 main

V1, V2, TBOUND, EMISIV
(10E10.3)

Card 4 from AERSOL, included only if aerosol attenuation

is to be included, i.e., IAERSL = 1
IHAZE, ISEASN, IVULCN, JP, VIS
(4,(4X,11), 5X, E10.3)

Card, 5, 6, 7 and the layer boundaries pertain to ATMPTH,
and are included only if IATM = 0

Card 5 MODEL, ITYPE, IIN, IMOD, KMAX, RE
(5I5, 5X, F10.4)

The formats for control cards 6 and 7 are different depending on whether the path is horizontal (ITYPE = 1) or slant (ITYPE = 2 or 3).

For a slant path-

Card 6 H1, H2, ANGLE, RANGE, BETA, LEN
(5F10.4, 15)

Next read in the boundary altitudes for the FASCOD1 layers,
with format (8F10.3).

Card 7 V1, V2,
(2F10.3)

For a horizontal path-

Card 6 Z, P, T, RANGE (DEN(K), K = 1, KMAX)
(4F10.3,/, (8E10.3)

For a model = 1 to 7, only Z and RANGE are used and P, T and DEN are interpolated. For model = 0, P and T are included.

Card 7 not used

For model 7, the input model atmosphere is read in after control card 5 as for a slant path;

(HEADER(1) I = 1,2) (2A10)

Z,P, T (3F10.3)

DENSITY (K), K = 1, KMAX (8E10.3)

Repeat the last two cards for each of the IMOD levels.

Card 8 from the scanning routine; this card is included only if ISCAN \neq 0

HWHM, V1, V2, JEMIT, JFN, JVAR
(3F10.3, 3(9X,11)

Card 9, 10, 11, 12 are plotting cards, and are included only if IPLOT \neq 0

Card 9 NAME, PHONE, EXTENSION, ID
(3A10)

Card 10 V1, V2, XSIZE, DEJV, NUMSBX, NOENDX, LFILE,
LSKIP, SCALE, IP⁴
(4F10.3, 4I5, F10.3, I5)

Card 11 YMIN, YMAX, YSIZE, DELY, NUMSBY, NOENDY, IDEC,
JEMIT, JPLOT, LOGPLT
(4F10.3, 6I5)

Card 12 Repeat card 10

If the user is supplying layer data (IATM \neq 0) then FILE 7 must contain the following information to be read by PATH.

NLAYRS (15)

The next two cards are repeated for J layers

TBAR(J), TBAR(J), DUMMY, ICNTRK(J)
(3F10.4, I5)
(AMOUN1(1,J) 1 = 1,8)
(8E10.3)

If aerosol attenuation is to be included it must also be supplied by repeating the following card for J layers

AWKAER(J) (E10.3)

Sample Input Sequence: The following sample input card sequence corresponds to a FASCOD1 run in the emission mode, including aerosols for a vertical path from 0 to 20 km, with a layer boundary every 1 km. Note that the scanning routine is used (ISCAN = 1), while the plotting routine which is machine dependent is not used (IPLOT = 0).

```

DATA FOR FASCOD2 REPORT, GROUND TO 20 KM, VERTICAL, AEROSOLS ON
HI=1 F4=1 CN=1 AE=1 EM=1 SC=1 FI=0 PL=0                2    2
2.095E+03 2.105E+03 0.000E+00 0.000E+00 0.000E+00
IH=1 IS=1 IV=1 JF=1      2.30E+01
  6    2    21
00.0    20.0    00.0
0.      1.      2.      3.      4.      5.      6.      7.
8.      9.     10.     11.     12.     13.     14.     15.
16.     17.     18.     19.     20.     21.     22.     23.
2090.   2110.
1.      2095.1   2104.95      0      3
-1.

```

Sample Output: The output has been truncated to include only output up to the second layer, plus the final layer and the results of the scanning routine. This should be sufficient for a user to verify that his copy of the code is functioning properly.

MODEL = 6
 TYPE = 2
 LEN = 21
 INCO = 34
 NMAX = 8
 RE = 6371.230

SLANT PATH SELECTED, ITYPE = 2

MODEL ATMOSPHERE SELECTED IS: M = 6

U. S. STANDARD, 1962

I	Z (KM)	P (MB)	T (K)	H2O	CO2	O3	N2O	DENSITY CH4 (MOL CM-3)	CO	O2	N2
1	0.000	1013.000	288.100	1.973E+17	8.342E+15	6.777E+11	7.078E+12	1.896E+12	4.045E+13	5.295E+18	1.974E+19
2	1.000	898.600	281.600	1.404E+17	7.583E+15	6.777E+11	6.434E+12	1.733E+12	3.677E+13	4.814E+18	1.794E+19
3	2.000	795.000	275.100	9.696E+16	6.878E+15	6.777E+11	5.835E+12	1.563E+12	3.335E+13	4.366E+18	1.627E+19
4	3.000	701.200	268.700	6.018E+16	6.220E+15	6.278E+11	5.277E+12	1.414E+12	3.016E+13	3.945E+18	1.472E+19
5	4.000	616.600	262.200	3.678E+16	5.611E+15	5.773E+11	4.760E+12	1.275E+12	2.720E+13	3.562E+18	1.328E+19
6	5.000	540.500	255.700	2.140E+16	5.047E+15	5.773E+11	4.282E+12	1.147E+12	2.447E+13	3.204E+18	1.194E+19
7	6.000	472.200	249.200	1.271E+16	4.526E+15	5.647E+11	3.841E+12	1.037E+12	2.195E+13	2.874E+18	1.071E+19
8	7.000	411.100	242.700	7.022E+15	4.048E+15	6.149E+11	3.434E+12	9.199E+11	1.962E+13	2.570E+18	9.578E+18
9	8.000	356.500	236.200	4.012E+15	3.607E+15	6.526E+11	3.061E+12	8.199E+11	1.749E+13	2.290E+18	8.536E+18
10	9.000	308.000	229.700	1.538E+15	3.205E+15	8.910E+11	2.720E+12	7.285E+11	1.554E+13	2.035E+18	7.585E+18
11	10.000	265.000	223.200	6.018E+14	2.839E+15	1.129E+12	2.408E+12	6.451E+11	1.376E+13	1.802E+18	6.717E+18
12	11.000	227.000	216.600	2.742E+14	2.503E+15	1.631E+12	2.124E+12	5.689E+11	1.214E+13	1.589E+18	5.924E+18
13	12.000	194.000	216.600	1.237E+14	2.141E+15	2.008E+12	1.817E+12	4.867E+11	1.038E+13	1.359E+18	5.067E+18
14	13.000	165.800	216.600	6.018E+13	1.830E+15	2.133E+12	1.553E+12	4.160E+11	8.674E+12	1.162E+18	4.331E+18
15	14.000	141.700	216.600	2.809E+13	1.564E+15	2.384E+12	1.327E+12	3.555E+11	7.584E+12	9.930E+17	3.701E+18
16	15.000	121.100	216.600	2.407E+13	1.337E+15	2.635E+12	1.134E+12	3.038E+11	6.481E+12	8.435E+17	3.163E+18
17	16.000	103.500	216.600	2.040E+13	1.142E+15	3.015E+12	9.694E+11	2.597E+11	5.539E+12	7.253E+17	2.704E+18
18	17.000	88.500	216.600	1.739E+13	9.759E+14	3.314E+12	8.209E+11	2.250E+11	4.737E+12	6.202E+17	2.312E+18

19	18.000	75.650	216.600	1.471E+13	8.351E+14	4.016E+12	7.085E+11	1.898E+11	4.049E+12	5.301E+17	1.976E+18
20	19.000	64.670	216.600	1.471E+13	7.139E+14	4.392E+12	6.057E+11	1.652E+11	3.461E+12	4.532E+17	1.489E+18
21	20.000	55.290	216.600	1.471E+13	6.103E+14	4.769E+12	5.178E+11	1.397E+11	2.959E+12	3.875E+17	1.444E+18
22	21.000	47.290	217.600	1.605E+13	5.196E+14	4.769E+12	4.409E+11	1.191E+11	2.519E+12	3.299E+17	1.230E+18
23	22.000	40.470	218.600	1.739E+13	4.426E+14	4.894E+12	3.756E+11	1.006E+11	2.146E+12	2.310E+17	1.047E+18
24	23.000	34.670	219.600	1.906E+13	3.775E+14	4.769E+12	3.203E+11	8.579E+10	1.830E+12	2.396E+17	8.932E+17
25	24.000	29.720	220.600	2.040E+13	3.221E+14	4.518E+12	2.733E+11	7.321E+10	1.562E+12	2.045E+17	7.822E+17
26	25.000	25.490	221.600	2.207E+13	2.750E+14	4.267E+12	2.333E+11	6.250E+10	1.333E+12	1.745E+17	6.508E+17
27	30.000	11.970	226.500	1.271E+13	1.264E+14	2.510E+12	1.072E+11	2.872E+10	6.126E+11	8.021E+15	2.990E+17
28	35.000	5.746	236.500	5.350E+12	5.809E+13	1.380E+12	4.929E+10	1.320E+10	2.816E+11	3.488E+16	1.375E+17
29	40.000	2.871	253.400	2.240E+12	2.709E+13	6.149E+11	2.293E+10	6.156E+09	1.313E+11	1.720E+16	6.410E+17
30	45.000	1.491	264.200	1.070E+12	1.349E+13	2.133E+11	1.145E+10	3.067E+09	6.542E+10	8.566E+15	3.193E+16
31	50.000	.798	270.600	4.012E+11	7.049E+12	5.020E+10	5.981E+09	1.602E+09	3.419E+10	4.475E+15	1.668E+16
32	70.000	.055	219.700	5.015E+09	6.907E+11	1.079E+09	5.097E+08	1.345E+08	2.913E+09	3.814E+14	1.422E+15
33	100.000	.000	210.000	3.344E+07	3.425E+09	5.396E+05	2.906E+06	7.784E+05	1.660E+07	2.174E+12	8.104E+12
34	99999.000	0.000	190.000	0.	0.	0.	0.	0.	0.	0.	0.

CONTROL CARD 2: SLANT PATH PARAMETERS

H1	=	0.0000 KM
H2	=	20.0000 KM
ANGLE	=	0.0000 DEG
RANGE	=	0.0000 KM
BETA	=	0.0000 DEG
LEN	=	0

BOUNDARY ALTITUDES FOR FASCOD1 LAYERS

I	Z (KM)
1	0.0000
2	1.0000
3	2.0000
4	3.0000
5	4.0000
6	5.0000
7	6.0000
8	7.0000
9	8.0000
10	7.0000

11 10.0000
12 11.0000
13 12.0000
14 13.0000
15 14.0000
16 15.0000
17 16.0000
18 17.0000
19 18.0000
20 19.0000
21 20.0000

CONTROL CARD 3

V1 = 2090.000 CM-1
V2 = 2110.000 CM-1
VBAR = 2100.000 CM-1

IMMERGED ATMOSPHERIC PROFILE: MODEL ATMOSPHERE PLUS FASCOD1 LAYER BOUNDARIES

THIS PROFILE IS THE INPUT ATMOSPHERE TO THE GEOMETRY CALCULATION

I	Z (KM)	P (MB)	T (K)	REFRACT INDEX-1 *1.0E+6	H2O	CO2	O3	DENSITY N2O (MOL CM-3)	CO	CH4	O2	N2
1	0.000	1013.000	288.100	272.098	1.973E+17	8.342E+15	6.777E+11	7.078E+12	1.896E+12	4.045E+12	5.276E+18	1.974E+19
2	1.000	895.600	281.600	247.012	1.404E+17	7.533E+15	6.777E+11	6.434E+12	1.723E+12	3.677E+13	4.814E+18	1.794E+19
3	2.000	795.000	275.100	223.751	9.696E+16	6.878E+15	6.777E+11	5.833E+12	1.563E+12	3.335E+13	4.366E+18	1.627E+19
4	3.000	701.200	268.700	202.099	6.018E+16	6.220E+15	6.275E+11	5.277E+12	1.414E+12	3.016E+13	3.742E+18	1.475E+19
5	4.000	616.600	262.200	182.151	3.678E+16	5.611E+15	5.773E+11	4.740E+12	1.275E+12	2.720E+13	3.562E+18	1.323E+19
6	5.000	540.500	255.700	163.749	2.140E+16	5.047E+15	5.773E+11	4.282E+12	1.147E+12	2.447E+13	3.204E+18	1.194E+19
7	6.000	472.200	249.200	146.797	1.271E+16	4.526E+15	5.647E+11	3.841E+12	1.027E+12	2.195E+13	2.874E+18	1.071E+19
8	7.000	411.100	242.700	131.232	7.022E+15	4.048E+15	6.149E+11	3.434E+12	9.199E+11	1.962E+13	2.570E+18	9.576E+18
9	8.000	356.500	236.200	116.938	4.012E+15	3.607E+15	6.526E+11	3.061E+12	8.199E+11	1.749E+13	2.390E+18	8.533E+18
10	9.000	308.000	229.700	103.891	1.538E+15	3.203E+15	8.910E+11	2.720E+12	7.285E+11	1.554E+13	2.035E+18	7.595E+18
11	10.000	265.000	223.200	91.991	6.018E+14	2.839E+15	1.127E+12	2.408E+12	6.431E+11	1.376E+13	1.802E+18	6.717E+18
12	11.000	227.000	216.800	81.126	2.742E+14	2.503E+15	1.631E+12	2.124E+12	5.689E+11	1.214E+13	1.589E+18	5.924E+18
13	12.000	194.000	216.600	69.397	1.237E+14	2.141E+15	2.008E+12	1.817E+12	4.867E+11	1.038E+13	1.359E+18	5.067E+18
14	13.000	165.800	216.600	59.309	6.018E+13	1.830E+15	2.133E+12	1.553E+12	4.130E+11	8.874E+12	1.162E+18	4.331E+18
15	14.000	141.700	216.600	50.688	2.809E+13	1.564E+15	2.384E+12	1.327E+12	3.535E+11	7.534E+12	9.930E+17	3.704E+18

16	15.000	121.100	216.600	43.319	2.407E+13	1.337E+15	2.635E+12	1.134E+12	3.039E+11	6.401E+12	8.486E+17	3.163E+18
17	16.000	103.500	216.600	37.024	2.040E+13	1.142E+15	3.012E+12	9.694E+11	2.597E+11	5.539E+12	7.255E+17	2.794E+18
18	17.000	88.500	216.600	31.658	1.739E+13	9.769E+14	3.514E+12	8.289E+11	2.220E+11	4.737E+12	6.302E+17	2.310E+18
19	18.000	75.650	216.600	27.061	1.471E+13	8.351E+14	4.016E+12	7.085E+11	1.899E+11	4.049E+12	5.301E+17	1.976E+18
20	19.000	64.670	216.600	23.133	1.471E+13	7.139E+14	4.392E+12	6.057E+11	1.623E+11	3.461E+12	4.832E+17	1.887E+18
21	20.000	55.290	216.600	19.778	1.471E+13	6.103E+14	4.769E+12	5.178E+11	1.387E+11	2.959E+12	3.875E+17	1.444E+18
22	21.000	47.590	217.600	16.039	1.606E+13	5.196E+14	4.769E+12	4.409E+11	1.181E+11	2.519E+12	3.299E+17	1.530E+18
23	22.000	40.470	218.600	14.344	1.739E+13	4.426E+14	4.894E+12	3.756E+11	1.003E+11	2.146E+12	2.810E+17	1.047E+18
24	23.000	34.670	219.600	12.233	1.906E+13	3.775E+14	4.769E+12	3.203E+11	8.579E+10	1.830E+12	2.398E+17	8.932E+17
25	24.000	29.720	220.600	10.439	2.040E+13	3.221E+14	4.518E+12	2.732E+11	7.324E+10	1.582E+12	2.045E+17	7.422E+17
26	25.000	25.490	221.600	8.912	2.207E+13	2.750E+14	4.267E+12	2.333E+11	6.250E+10	1.333E+12	1.745E+17	6.530E+17
27	30.000	11.970	226.500	4.095	1.271E+13	1.264E+14	2.510E+12	1.072E+11	2.872E+10	6.126E+11	8.021E+16	2.990E+17
28	35.000	5.746	236.500	1.892	5.390E+12	5.809E+13	1.380E+12	4.929E+10	1.320E+10	2.816E+11	3.688E+16	1.375E+17
29	40.000	2.871	253.400	.878	2.240E+12	2.709E+13	6.149E+11	2.290E+10	6.153E+09	1.313E+11	1.720E+16	6.410E+16
30	45.000	1.491	264.200	.437	1.070E+12	1.349E+13	2.133E+11	1.145E+10	3.067E+09	6.542E+10	8.566E+15	3.193E+16
31	50.000	.798	270.600	.228	4.012E+11	7.049E+12	5.020E+10	5.981E+09	1.602E+09	3.418E+10	4.475E+15	1.660E+16
32	70.000	.055	219.700	.019	5.015E+09	6.007E+11	1.079E+09	5.097E+08	1.565E+08	2.913E+09	3.814E+14	1.422E+15
33	100.000	.000	210.000	.000	3.344E+07	3.425E+09	5.396E+05	2.906E+06	7.784E+05	1.660E+07	2.174E+12	8.104E+12
34	99999.000	0.000	190.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

ISLAND PATH PARAMETERS AFTER INPUT PROCESSING

H1 = 0.000 KM
H2 = 20.000 KM
ANGLE = 0.000 DEG
HMIN = 0.000 KM
LEN = 0

1. CALCULATION OF THE REFRACTED PATH THROUGH THE ATMOSPHERE

I	ALTITUDE FROM (KM)	TO (NM)	THETA (DEG)	D RANGE (KM)	RANGE (NM)	BETA (DEG)	DBETA (DEG)	PHI (DEG)	DBEND (DEG)	PBAR (MR)	TRBAR (K)	RHOBAR (K) (POL CH-2)
---	--------------------------	------------	----------------	-----------------	---------------	---------------	----------------	--------------	----------------	--------------	--------------	--------------------------

0	9	9.000	7.580E+20	3.402E+20	7.656E+16	2.897E+17	7.733E+16	1.650E+18	2.160E+23	8.051E+23
0	10	9.000	9.977E+19	3.018E+20	1.005E+17	2.531E+17	6.860E+16	1.463E+18	1.916E+23	7.142E+23
0	11	10.000	2.140E+19	2.667E+20	1.365E+17	2.263E+17	6.062E+16	1.293E+18	1.693E+23	6.712E+23
0	12	11.000	1.891E+19	2.317E+20	1.013E+17	1.967E+17	5.267E+16	1.124E+18	1.471E+23	5.484E+23
0	13	12.000	8.816E+18	1.903E+20	2.070E+17	1.682E+17	4.504E+16	9.607E+17	1.758E+23	4.699E+23
0	14	13.000	4.212E+18	1.594E+20	2.256E+17	1.437E+17	3.950E+16	8.212E+17	1.075E+23	4.008E+23
0	15	14.000	2.603E+18	1.448E+20	2.507E+17	1.220E+17	3.290E+16	7.018E+17	9.189E+22	3.425E+23
0	16	15.000	2.218E+18	1.237E+20	2.019E+17	1.050E+17	2.812E+16	5.998E+17	7.353E+22	2.929E+23
0	17	16.000	1.885E+18	1.057E+20	3.257E+17	8.975E+16	2.404E+16	5.128E+17	6.714E+22	2.503E+23
0	18	17.000	1.601E+18	9.011E+19	3.759E+17	7.671E+16	2.055E+16	4.384E+17	5.740E+22	2.140E+23
0	19	18.000	1.471E+18	7.729E+19	4.201E+17	6.558E+16	1.756E+16	3.747E+17	4.906E+22	1.827E+23
0	20	19.000	1.471E+18	6.607E+19	4.578E+17	5.606E+16	1.501E+16	3.203E+17	4.195E+22	1.563E+23

INITIAL SET OF LAYERS FOR INPUT TO FASCOM31
IF THE RATIO OF THE THICKNESSES OF TWO ADJACENT LAYERS IS GREATER THAN 10.0,
THEN PERGE THESE LAYERS

L	LAYER BOUNDARIES FROM (KM)	ICNTRL TO (KM)	PBAR (MB)	TSAR (K)	AIR	H2O	CO2	INTEGRATED AMOUNTS					
								O3	NO	CH4	O2	N2	
1	0.000	1.000	955.58	284.80	2.43E+24	1.67E+22	7.94E+20	6.78E+16	6.75E+17	1.81E+17	3.86E+18	7.05E+23	1.88E+24
2	1.000	2.000	846.60	278.39	2.20E+24	1.17E+22	7.22E+20	6.78E+16	6.13E+17	1.64E+17	3.50E+18	4.59E+23	1.71E+24
3	2.000	3.000	747.92	271.94	1.90E+24	7.71E+21	6.54E+20	6.52E+16	3.55E+17	1.49E+17	3.17E+18	4.15E+23	1.55E+24
4	3.000	4.000	658.73	265.49	1.60E+24	4.78E+21	5.91E+20	6.02E+16	5.01E+17	1.34E+17	2.87E+18	3.75E+23	1.40E+24
5	4.000	5.000	578.39	258.99	1.62E+24	2.84E+21	5.32E+20	5.77E+16	4.52E+17	1.21E+17	2.58E+18	3.38E+23	1.24E+24
6	5.000	6.000	506.20	252.50	1.45E+24	1.67E+21	4.70E+20	5.71E+16	4.06E+17	1.09E+17	2.32E+18	3.04E+23	1.13E+24
7	6.000	7.000	441.62	246.00	1.30E+24	9.89E+20	4.28E+20	5.89E+16	3.63E+17	9.73E+16	2.08E+18	2.72E+23	1.01E+24

8	7.000	8.000	1	383.68	239.50	1.16E+24	5.39E+20	3.82E+20	6.74E+16	3.24E+17	8.39E+16	1.65E+18	2.43E+23	9.05E+23
9	8.000	9.000	1	332.14	233.00	1.03E+24	2.59E+20	3.40E+20	7.66E+16	2.69E+17	7.73E+16	1.65E+18	2.16E+23	8.05E+23
10	9.000	10.000	1	286.40	226.50	9.14E+23	9.90E+19	3.02E+20	1.01E+17	2.56E+17	6.86E+16	1.46E+18	1.92E+23	7.14E+23
11	10.000	11.000	1	245.91	220.05	8.05E+23	4.17E+19	2.67E+20	1.36E+17	2.26E+17	6.06E+16	1.29E+18	1.69E+23	6.31E+23
12	11.000	12.000	1	210.50	216.70	7.02E+23	1.89E+19	2.32E+20	1.91E+17	1.97E+17	5.27E+16	1.12E+18	1.47E+23	5.46E+23
13	12.000	13.000	1	179.90	216.60	6.00E+23	8.82E+18	1.98E+20	2.07E+17	1.68E+17	4.50E+16	9.61E+17	1.26E+23	4.69E+23
14	13.000	14.000	1	153.75	216.60	5.13E+23	4.21E+18	1.69E+20	2.25E+17	1.44E+17	3.85E+16	8.21E+17	1.02E+23	4.01E+23
15	14.000	15.000	1	131.40	216.60	4.39E+23	2.60E+18	1.45E+20	2.51E+17	1.23E+17	3.27E+16	7.02E+17	9.19E+22	3.41E+23
16	15.000	16.000	1	112.30	216.60	3.75E+23	2.23E+18	1.24E+20	2.03E+17	1.05E+17	2.81E+16	6.00E+17	7.05E+22	2.52E+23
17	16.000	17.000	1	94.00	216.60	3.20E+23	1.89E+18	1.06E+20	3.24E+17	8.97E+16	2.40E+16	5.13E+17	6.71E+22	2.50E+23
18	17.000	18.000	1	82.07	216.60	2.74E+23	1.60E+18	9.04E+19	3.76E+17	7.67E+16	2.05E+16	4.38E+17	5.74E+22	2.14E+23
19	18.000	19.000	1	70.16	216.60	2.34E+23	1.47E+18	7.73E+19	4.20E+17	6.56E+16	1.76E+16	3.75E+17	4.91E+22	1.83E+23
20	19.000	20.000	1	59.98	216.60	2.00E+23	1.47E+18	6.61E+19	4.58E+17	5.61E+16	1.50E+16	3.20E+17	4.19E+22	1.56E+23

AVERAGE RELATIVE HUMIDITY FROM 0 TO 2 KM IS .396E+02

0 U(CM-1) = 2095.0000

0 V(CM-1) = 2105.0000

0 T(BOUND) = 0.0000 BOUNDARY EMISSIVITY = 0.00000

0 LINE FILE INFORMATION
0 OLIVE PARAMETERS TAPE IS ONLY SOURCE FOR FACCD01

BCDRG1 79/11/12. 10.38.40.

H2O	=	65	4.1993E-25
CO2	=	333	1.6437E-25
O3	=	402	1.9995E-22
H2O	=	0	0.
CO	=	23	6.5488E-22
CH4	=	0	0.
O2	=	0	0.

0 LOWEST LINE = 2090.042

HIGHEST LINE = 2109.990

TOTAL NUMBER OF LINES =

823

FASC001 80/08/02. 14.43.04.

DATA FOR EASTCO2 REPORT, GROUND TO 20 KM, VERTICAL AEROSOL: NN

```
0 LAYER =
0 PRESS(MB) = 933.53254
0 TEMP(K) = 284.84
0 SECAIT = 1.00000
```

Year	1950	1951	1952	1953	1954	1955
Population	1,672E+22	2,955E+20	6,777E+16	6,751E+17	1,608E+17	2,858E+16
Area	3,051E+23					

```

      #2 = 1.083E+24
      0 WKAER = .12835E+00
      0 SELF EXAMINING FACTOR FOR H2D IS 1.02701
      0 COMPUTED DV BEFORE MODIFICATION = .02471832
      0 TYPE OF PATH = 1
      0 RATIO OF PREVIOUS DV TO CURRENT DV = 0.0000
      0 TYPE OF HESE 99
      0 DV FOR THE LAYER .02470000

```

16.4000 .06260 .03469 .01741 .01722 .03665 .14574 .12309
 17.2000 .07159 .03975 .01766 .01747 .04152 .13373 .10351
 18.0000 .08957 .03360 .01513 .01506 .01709 .18248 .16134
 19.0000 .08212 .03384 .01557 .01531 .01620 .10150 .07035
 20.0000 .05322 .03387 .01124 .01424 .00935 .12924 .10032
 21.0000 .04703 .03391 .01522 .01532 .00633 .08529 .06759
 22.0000 .04393 .03455 .01582 .01502 .00589 .04108 .03247
 23.0000 *****
 24.0000 *****

***** CONTINUOUS ARE INTERIM (04/24/79) *****

0 * LBLF4 * 1.58080 ROUND FOR LBLF4 = 25.2928

0 FIRST LINE USED IN RBLINA --- CHECK THE LINEFIL

0 EOF ON LINEFIL IN RBLINA --- CHECK THE LINEFIL

0 TIME 1.247 READ CONVOLUTION .007

0 * HIRAC1 * 1.009

0 OUTPUT ON FILE 10 DV = .02470000

0 FIRST LINE ON LINEFIL USED (MORE LINES MAY BE REQUIRED)

0 EOF ON LINEFIL (MORE LINES MAY BE REQUIRED)

1025 2095.000000 .21251000E+00

1026 2095.024700 .21575000E+00

1027 2104.973300 .71521000E+01

1430 2105.003500 .76247000E+01

0 TIME 1.247 READ CONVOLUTION .007

0 AVERAGE LINES = .08051 AVERAGE ZETA = .97602

1 2095.000000 .20951100E-07 .50824974E+03

2 2095.024700 .50718100E-07 .75760946E+00

405 2104.973300 .18037200E-07 .93855400E+00

406 2105.003500 .14308452E-07 .92974933E+00

0 TIME REQUIRED FOR REMINIT-- .013

0 DATA FOR FASCOT REPORT. GROUND TO 20 NM, VERTICAL/AEROSOLS ON

0 LAYER = 2

0 PRESS(MR) = 846.59847

0 TEMP(C) = 278.13

0 SEDANT = 1.00000

0 H2 = 1.709E+24

0 C1 = 7.125E+20

0 C2 = 6.777E+16

0 C3 = 6.123E+17

0 C4 = 1.645E+17

0 C5 = 3.503E+18

0 C6 = 4.505E+23

0 N2 = 1.709E+24

0 WKAER = .7914E-01

0 SELF DETERMINING FACTOR FOR H2O IS 1.02153

0 COMPUTED BY BEFORE NOTIFICATION = .02202022

0 TYPE OF PAIR = 1

0 RATIO OF PREVIOUS DV TO CURRENT DV = 1.1217

0 TYPE OF MERGE = 0

0 DV FOR THE LAYER .02470000

0 ***** CONTINUOUS ARE INTERIM (04/24/79) *****

0 * LBLF4 *

0 DV FOR LBLF4 = 1.58080 ROUND FOR LBLF4 = 25.2928

0 FIRST LINE USED IN RBLINA --- CHECK THE LINEFIL

0 EOF ON LINEFIL IN RBLINA --- CHECK THE LINEFIL

0 TIME 1.247 READ CONVOLUTION .007

0 * HIRAC1 *

0 OUTPUT ON FILE 10 DV = .02470000

0 FIRST LINE ON LINEFIL USED (MORE LINES MAY BE REQUIRED)

0 EOF ON LINEFIL (MORE LINES MAY BE REQUIRED)

1025 2095.000000 .21251000E+00

1026 2095.024700 .21575000E+00

1027 2104.973300 .71521000E+01

1430 2105.003500 .76247000E+01

0 TIME 1.247 READ CONVOLUTION .007

0 AVERAGE LINES = .08051 AVERAGE ZETA = .97602

1 2095.000000 .20951100E-07 .50824974E+03

2 2095.024700 .50718100E-07 .75760946E+00

405 2104.973300 .18037200E-07 .93855400E+00

406 2105.003500 .14308452E-07 .92974933E+00

0 TIME REQUIRED FOR REMINIT-- .013

0 DATA FOR FASCOT REPORT. GROUND TO 20 NM, VERTICAL/AEROSOLS ON

0 LAYER = 2

0 PRESS(MR) = 846.59847

0 TEMP(C) = 278.13

0 SEDANT = 1.00000

0 H2 = 1.709E+24

0 C1 = 7.125E+20

0 C2 = 6.777E+16

0 C3 = 6.123E+17

0 C4 = 1.645E+17

0 C5 = 3.503E+18

0 C6 = 4.505E+23

0 N2 = 1.709E+24

0 WKAER = .7914E-01

0 SELF DETERMINING FACTOR FOR H2O IS 1.02153

0 COMPUTED BY BEFORE NOTIFICATION = .02202022

0 TYPE OF PAIR = 1

0 RATIO OF PREVIOUS DV TO CURRENT DV = 1.1217

0 TYPE OF MERGE = 0

0 DV FOR THE LAYER .02470000

0 ***** CONTINUOUS ARE INTERIM (04/24/79) *****

0 * LBLF4 *

0 DV FOR LBLF4 = 1.58080 ROUND FOR LBLF4 = 25.2928

0 FIRST LINE USED IN RBLINA --- CHECK THE LINEFIL

0 EOF ON LINEFIL IN RBLINA --- CHECK THE LINEFIL

0 TIME 1.247 READ CONVOLUTION .007

0 * HIRAC1 *

0 OUTPUT ON FILE 10 DV = .02470000

0 FIRST LINE ON LINEFIL USED (MORE LINES MAY BE REQUIRED)

0 EOF ON LINEFIL (MORE LINES MAY BE REQUIRED)

1025 2095.000000 .21251000E+00

1026 2095.024700 .21575000E+00

1027 2104.973300 .71521000E+01

1430 2105.003500 .76247000E+01

0 TIME 1.247 READ CONVOLUTION .007

0 AVERAGE LINES = .08051 AVERAGE ZETA = .97602

1 2095.000000 .20951100E-07 .50824974E+03

2 2095.024700 .50718100E-07 .75760946E+00

405 2104.973300 .18037200E-07 .93855400E+00

406 2105.003500 .14308452E-07 .92974933E+00

0 TIME REQUIRED FOR REMINIT-- .013

0 DATA FOR FASCOT REPORT. GROUND TO 20 NM, VERTICAL/AEROSOLS ON

0 LAYER = 2

0 PRESS(MR) = 846.59847

0 TEMP(C) = 278.13

0 SEDANT = 1.00000

0 H2 = 1.709E+24

0 C1 = 7.125E+20

0 C2 = 6.777E+16

0 C3 = 6.123E+17

0 C4 = 1.645E+17

0 C5 = 3.503E+18

0 C6 = 4.505E+23

0 N2 = 1.709E+24

0 WKAER = .7914E-01

0 SELF DETERMINING FACTOR FOR H2O IS 1.02153

0 COMPUTED BY BEFORE NOTIFICATION = .02202022

0 TYPE OF PAIR = 1

0 RATIO OF PREVIOUS DV TO CURRENT DV = 1.1217

0 TYPE OF MERGE = 0

0 DV FOR THE LAYER .02470000

0 ***** CONTINUOUS ARE INTERIM (04/24/79) *****

0 * LBLF4 *

0 DV FOR LBLF4 = 1.58080 ROUND FOR LBLF4 = 25.2928

0 FIRST LINE USED IN RBLINA --- CHECK THE LINEFIL

0 EOF ON LINEFIL IN RBLINA --- CHECK THE LINEFIL

0 TIME 1.247 READ CONVOLUTION .007

0 * HIRAC1 *

0 OUTPUT ON FILE 10 DV = .02470000

0 FIRST LINE ON LINEFIL USED (MORE LINES MAY BE REQUIRED)

0 EOF ON LINEFIL (MORE LINES MAY BE REQUIRED)

1025 2095.000000 .21251000E+00

1026 2095.024700 .21575000E+00

1027 2104.973300 .71521000E+01

1430 2105.003500 .76247000E+01

0 TIME 1.247 READ CONVOLUTION .007

0 AVERAGE LINES = .08051 AVERAGE ZETA = .97602

1 2095.000000 .20951100E-07 .50824974E+03

2 2095.024700 .50718100E-07 .75760946E+00

405 2104.973300 .18037200E-07 .93855400E+00

406 2105.003500 .14308452E-07 .92974933E+00

0 TIME REQUIRED FOR REMINIT-- .013

0 DATA FOR FASCOT REPORT. GROUND TO 20 NM, VERTICAL/AEROSOLS ON

0 LAYER = 2

0 PRESS(MR) = 846.59847

0 TEMP(C) = 278.13

0 SEDANT = 1.00000

0 H2 = 1.709E+24

0 C1 = 7.125E+20

0 C2 = 6.777E+16

0 C3 = 6.123E+17

0 C4 = 1.645E+17

0 C5 = 3.503E+18

0 C6 = 4.505E+23

0 N2 = 1.709E+24

0 WKAER = .7914E-01

0 SELF DETERMINING FACTOR FOR H2O IS 1.02153

0 COMPUTED BY BEFORE NOTIFICATION = .02202022

0 TYPE OF PAIR = 1

0 RATIO OF PREVIOUS DV TO CURRENT DV = 1.1217

0 TYPE OF MERGE = 0

0 DV FOR THE LAYER .02470000

0 ***** CONTINUOUS ARE INTERIM (04/24/79) *****

0 * LBLF4 *

0 DV FOR LBLF4 = 1.58080 ROUND FOR LBLF4 = 25.2928

0 FIRST LINE USED IN RBLINA --- CHECK THE LINEFIL

0 EOF ON LINEFIL IN RBLINA --- CHECK THE LINEFIL

0 TIME 1.247 READ CONVOLUTION .007

0 * HIRAC1 *

0 OUTPUT ON FILE 10 DV = .02470000

0 FIRST LINE ON LINEFIL USED (MORE LINES MAY BE REQUIRED)

0 EOF ON LINEFIL (MORE LINES MAY BE REQUIRED)

1025 2095.000000 .21251000E+00

1026 2095.024700 .21575000E+00

1027 2104.973300 .71521000E+01

1430 2105.003500 .76247000E+01

0 TIME 1.247 READ CONVOLUTION .007

0 AVERAGE LINES = .08051 AVERAGE ZETA = .97602

1 2095.000000 .20951100E-07 .50824974E+03

2 2095.024700 .50718100E-07 .75760946E+00

405 2104.973300 .18037200E-07 .93855400E+00

406 2105.003500 .14308452E-07 .92974933E+00

0 TIME REQUIRED FOR REMINIT-- .013

0 DATA FOR FASCOT REPORT. GROUND TO 20 NM, VERTICAL/AEROSOLS ON

0 LAYER = 2

0 PRESS(MR) = 846.59847

0 TEMP(C) = 278.13

0 SEDANT = 1.00000

0 H2 = 1.709E+24

0 C1 = 7.125E+20

0 C2 = 6.777E+16

0 C3 = 6.123E+17

0 C4 = 1.645E+17

0 C5 = 3.503E+18

0 C6 = 4.505E+23

0 N2 = 1.709E+24

0 WKAER = .7914E-01

0 SELF DETERMINING FACTOR FOR H2O IS 1.02153

0 COMPUTED BY BEFORE NOTIFICATION = .02202022

0 TYPE OF PAIR = 1

0 RATIO OF PREVIOUS DV TO CURRENT DV = 1.1217

0 TYPE OF MERGE = 0

0 DV FOR THE LAYER .02470000

0 ***** CONTINUOUS ARE INTERIM (04/24/79) *****

0 * LBLF4 *

0 DV FOR LBLF4 = 1.58080 ROUND FOR LBLF4 = 25.2928

0 FIRST LINE USED IN RBLINA --- CHECK THE LINEFIL

0 EOF ON LINEFIL IN RBLINA --- CHECK THE LINEFIL

0 TIME 1.247 READ CONVOLUTION .007

0 * HIRAC1 *

0 OUTPUT ON FILE 10 DV = .02470000

0 FIRST LINE ON LINEFIL USED (MORE LINES MAY BE REQUIRED)

BOUNDF3(CM-1) = 6.3232

OUTPUT ON FILE 10 DU = .02470000
FIRST LINE ON LINEIL USED (MORE LINES MAY BE REQUIRED)
END ON LINEIL (MORE LINES MAY BE REQUIRED)

1022 2095.000000 .13793228E+00
1026 2095.024700 .15373186E+00
1429 2104.978800 .45237849E-01
1430 2105.003500 .45974005E-01

0 0 AVERAGE WIDTH = 1.986 CONVOLUTION = .272
0 0 THE TIME AT THE START OF RAINRG IS .07752 AVERAGE ZETA = .97366 NO. LINES = 823 NO. CHANGES = 0

1 2095.000000 .71114184E-07 .70435447E+00
2 2095.024700 .78453332E-07 .67537528E+00
405 2104.978800 .23376408E-07 .88977643E+00
404 2105.003500 .23763079E-07 .88820477E+00

0 0 THE TIME AT THE END OF RAINRG IS 2.002
.015 SECS WERE REQUIRED FOR THIS MERGE

1 0 DATA FOR FASCO1/2 REPORT, GROUND TO 20 KM, VERTICAL, AEROSOLS ON
FASCO1 00/03/01, 14.43.04.

0 LAYER = 20
0 PRESS(MB) = 57.98000
0 TEMPER = 216.60
0 SECAT = 1.00000

H2O = 1.471E+18
SO2 = 6.007E+19
O3 = 4.578E+17
N2O = 2.606E+16
CO = 1.501E+16
CH4 = 7.202E+17
O2 = 4.195E+22

H2 = 1.563E+23
UNAR = .58499E-03
0 SELF BRADENING FACTOR FOR H2O IS 1.00003
0 COMPUTED DU BEFORE MODIFICATION = .00184575
TYPE OF PATH = 1
RATIO OF PREVIOUS DU TO CURRENT DU = 1.3549
TITS OF MERGE 3
0 DU FOR THE LAYER .00187566
0 ***** CONTINUUMS ARE INTERIM (04/24/79) *****

0 DU FOR LPLF4 = .12004 ROUND FOR LPLF4 = 1.9207
0 TIME READ CONVOLUTION PANEL
9.406 .005 .044 .001

0 * HTRAC1 * DU = .06187566 BOUNDF3(CM)

-17 = .4802
1025 2095.000000 .07030616E-01
1026 2095.001876 .01532800E-01
2431 2097.637173 .72463476E-02
2432 2097.639648 .24733105E-02
33 2097.640523 .26649310E-02
34 2097.641700 .28632146E-02
2431 2103.138748 .31831572E-02
2432 2102.140423 .34202111E-02
33 2102.142499 .77118442E-02
34 2102.144375 .41623181E-02
1535 2104.967248 .41900275E-02
1536 2104.999123 .75420034E-02

0 0 AVERAGE WIDTH = 2.623 CONVOLUTION = .183
0 0 THE TIME AT THE START OF RAINRG IS .00482 AVERAGE ZETA = .77953 NO. LINES = 454 NO. CHANGES = 0

O THE TIME AT THE START OF RADMRG IS 9.654
 1 2095.000000 .55446851E-07 .35880728E+00
 2 2095.001876 .56321966E-07 .36444128E+00
 1407 2097.637173 .76589018E-07 .59110297E+00
 1408 2097.639048 .75904442E-07 .59297272E+00
 1 2097.640924 .75320149E-07 .59467820E+00
 2 2097.642800 .74333068E-07 .59618769E+00
 2399 2102.138748 .24917037E-07 .82871025E+00
 2400 2102.140623 .24882769E-07 .82770311E+00
 1 2102.142499 .24842629E-07 .82634540E+00
 2 2102.144375 .24795136E-07 .82455650E+00
 1523 2104.997248 .27755935E-07 .79083859E+00
 1524 2104.999123 .27840110E-07 .79446629E+00
 O THE TIME AT THE END OF RADMRG IS 9.898
 .244 SECS WERE REQUIRED FOR THIS MERGE
 1 DATA FOR FASCOR2 REPORT, GROUND TO 20 KM, VERTICAL AEROSOLS ON
 FASCOR1 80/08/01. 14.43.04.

O SECANT = 0.00000
 O PRESS(MB) = 59.98000
 O TEMP(K) = 216.60
 O DV(CM-1) = .00187566
 O V1(CM-1) = 2095.000000
 O V2(CM-1) = 2105.000000
 O LAYER = 20
 O COLUMN DENSITY (MOLECULES/CM**2)

H2O = 4.737E+22
 CO2 = 6.701E+21
 O3 = 3.538E+18
 N2O = 5.685E+18
 CO = 1.523E+18
 CH4 = 3.249E+19
 O2 = 4.254E+24

*** SINCSO ***

INPUT FILE NUMBER = 12, JEMIT = 0 JFN = 3
 HIGH OF INSTRUMENT FUNCTION = 1.00000000 CM-1
 LOW OF INSTRUMENT FUNCTION = 4.52000000 CM-1
 OUTPUT FILE NUMBER = 11, V1 = 2095.10000, V2 = 2104.95000
 DV OUT .25000000
 NF = 226, DXF = .02000, SUM = .997436312531470

SHRINK RATIO = 16
 END OF FILE ENCOUNTERED
 TIME = 9.769, READ = .004, CONV. = .052, PANEL = 0.000
 SUMIN = .6413223358E+01

1 VIP = 2095.10000 V2P = 2104.85000 DVOUT = .25000000 NLIM =
 40
 0
 .36382E+00 .44527E+00 .51555E+00 .56811E+00 .59998E+00 .61144E+
 00 .60729E+00 .59449E+00 .58093E+00 .57293E+00
 0 .68123E+00 .67046E+00 .66034E+00 .65088E+00 .63952E+00 .62191E+
 00 .59326E+00 .54977E+00 .49009E+00 .41674E+00
 SUMOUT .589029948E+01